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THE GEODETIC SURVEY OF CANADA

BY NOEL OGILVIE, *Superintendent*

Every civilized nation recognizes the need for having geodetic surveys that are used to control the detailed mapping and surveying and its engineering work.

The need of a geodetic survey has long been felt in Canada. The absence of accurate maps has caused the expenditure of thousands and thousands of dollars on surveys which would never have been needed had a geodetic and a topographic survey been made long ago.

The main object of a geodetic survey is to furnish the control necessary for all other surveys. This control includes the determination of relative positions of a comparatively few widely separated points on the earth's surface, and the directions and lengths of the lines joining them. Without such accurate locations the errors of ordinary surveys would accumulate until they would overcome the needed accuracy of the survey and any map depending upon it. Indeed, the primary triangulation of the Geodetic Survey of Canada, by its corrective functions, stands in the same relation to other surveys as the Supreme Court of Canada stands to all lesser courts.

With the extension of the Geodetic Survey work many benefits to Canada will accrue. These benefits will not only be the fulfilling of demands, which have long been felt; but will be of many other kinds of which I shall treat briefly under separate heads.

Practical.—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts and sewage

plants may be laid out on these maps and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoirs, routes of canals, data for equitable assessments for drainage schemes, etc., may also be ascertained. The necessity of hydrographic and topographic maps of our sea-coasts and great waterways is so obvious as scarcely to need mentioning.

Administrative and Military.—In all questions relating to federal or provincial public works, as canals, reservations, parks, highways and postal service, and military maps on which to plan works of offence or defence, camps, marches, etc.

Economic.—As a means for showing the location, extent and accessibility of lands, waters, forests and valuable minerals. In this respect these maps are indispensable to provincial and federal bureaus and to owners, investors and corporations.

Political.—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

Educational.—(*a*) By promoting an exact knowledge of the country; (*b*) by serving teachers and pupils in geographical studies.

Scientific.—By providing the data for determinations of the figure, size and density of the earth.

In the above connection it is necessary to mention that a geodetic survey is an integral part of a topographic map. Just as a foundation is part of a house, and, just as the foundation is built before the superstructure, so a geodetic survey should be made *in advance of a topographic survey.*

Organization of the Geodetic Survey

From time to time efforts were made towards starting a Geodetic Survey of Canada, and finally, in 1905, the late Dr. King was authorized to commence operations in the vicinity of Ottawa.

In 1909 the survey was organized by order-in-council, and Dr. King was given the title of Superintendent.

Previous to 1914 the staff of the Survey was quartered partly in the Dominion Observatory and partly in the Trafalgar Building. In 1914 a building was completed for the use of the Survey Staff at 980 Carling Avenue, Ottawa.

As I have mentioned, in 1905 Dr. W. F. King received authority

of the Minister of Interior to commence Primary triangulation in the vicinity of Ottawa. During the summer a portion of country between the Ottawa and St. Lawrence rivers was explored for the purpose of selecting stations for the angular points of the triangulation system.

During 1906 this work was continued southward and eastward

Geodetic Survey of Canada: Offices, 980 Carling Avenue, Ottawa.

of Ottawa, and, as the level nature of the country required the erection of towers from which to take the necessary observations, a tower-building party was organized and started in its operations.

The year 1907 saw the commencement of the observing of the horizontal angles. The reconnaissance was carried eastward into the Eastern Townships of Quebec and west of Ottawa.

In 1908 the reconnaissance was continued eastward and westward in Quebec and Ontario, the observing being continued as far

west as Toronto and eastward into Quebec. This year also saw a reconnaissance started in the Bay of Fundy region, N.B.

Since 1909 reconnaissance and observing have been continued more or less continuously in New Brunswick, Nova Scotia, Quebec and Ontario. During this same year reconnaissance was started along the British Columbia coast and in the Lake Superior district

Standardizing Building of the Geodetic Survey, Ottawa.

in the region from Port Arthur westward along the International Boundary.

In 1910 and 1911 observing was commenced in the Port Arthur and British Columbia coast regions, respectively.

In 1910 a geodesist's office was established in charge of W. M. Tobey, D.T.S., in order that field data might be adjusted and harmonized before being published, and that geodetic methods

should be studied and applied to the direction and improvement of field methods.

At the end of 1917 the necessary field data were secured which permitted the ultimate publishing of final values of the geographic positions of all located points from Riviere du Loup, Quebec, westward to Windsor, Ontario.

Only preliminary values of positions in British Columbia, the Port Arthur region and the Bay of Fundy district, will be available for some time to come.

Summary of Work Done

Mileage.—Observations have already been completed over an area of about 88,000 square miles of land and water, the distribution of this amount being approximately as follows:

Maritime Provinces, largely in the vicinity of the Bay of Fundy and northward into New Brunswick and eastward across Nova Scotia to Cape Breton Island about.	16,000 square miles
Quebec, on both sides of the St. Lawrence and Ottawa rivers from Gaspe Peninsula to Ottawa, and covering the whole of the Eastern Townships, about.....	30,000 " "
Ontario, from Ottawa to Collingwood and Windsor, and 2,700 square miles in the Port Arthur region, about...	27,000 " "
British Columbia, from Victoria and Vancouver north between Vancouver island and the mainland, together with a scheme beginning at Dixon Entrance which is to be extended southward to meet the triangulation from the south, about.....	15,000 " "
Total, approximately.....	88,000 square miles

Reconnaissance surveys, looking to the extension of the triangulation, have also been made over an additional area of about 70,000 square miles, but the observations have not yet been taken.

It will be noticed that the areas covered by the Geodetic Survey have been such as to give control to topographic and hydrographic surveys along our waterways, and in the more densely settled parts of the country. This is, of course, the direct function of the Geodetic Survey of Canada. The scientific problems which may be solved from the field data secured, although very important in themselves, are of relatively secondary consequence to the economic value of Survey results.

Base Lines.—The accuracy of the computed distances between triangulation stations has been well controlled by eight base lines measured near Amherst, N.S.; St. Jean Port Joli, Que.; Coteau Junction, Que.; Belleville, Ont.; Collingwood, Ont.; Glencoe, Ont.; and two on the Pacific Coast.

These base lines have been measured with 50-metre invar tapes whose lengths are standardized at necessary intervals at the Standardizing Building of this Survey.

Laplace Work.—The Laplace work of the Survey consists in the establishment of Laplace stations—points at which the longitude and azimuth have been observed. They are placed at intervals of approximately 150 miles along the course of the triangulation system. They are established in order to correct the lateral deflection of the system, called the *twist*.

Precise levelling was started in 1906, and has advanced at the average rate of about 900 miles per year. In 1916 a line from the Atlantic to the Pacific was run across Canada, the error of closure being about one and a half feet.

In order that early aid might be given those requiring field data it was found necessary to start the work from five different bench marks or reference points, in widely separated parts of the country. Each of these was connected—more or less directly with mean sea level. The different sections are as follows:

(1) Lines of levelling in the Maritime Provinces, based in part on mean sea level at Halifax as deduced by the Tidal and Current Survey, Naval Service Department, and in part on a datum at St. Stephen, N.B., established by United States Engineers in 1873.

(2) Lines of levelling in Ontario and Quebec are based on the United States Coast and Geodetic Survey bench mark at Rouse Point, N.Y.

(3) Lines of levelling in the Lake Superior district, east of Port Arthur, are based on the United States Coast and Geodetic Survey bench mark at Rouse Point, N.Y., and those west of Port Arthur are based on the same organization's bench mark at Stephen, Minn.

(4) Lines of levelling in the Prairie Provinces are based on a bench mark at Stephen, Minn.

The number of miles of precise levelling since the inception of the work in 1906 up to, and including the 1920 operations, is distributed among the provinces as follows:

Ontario	4102	Miles
Quebec	1776	"
British Columbia	1781	"
Alberta	1481	"
Saskatchewan	1793	"
New Brunswick	864	"
Nova Scotia	705	"
Manitoba	982	"
Minnesota, U.S.A.	89	"
Yukon Territory	458	"
Total	14,031	"

The total number of standard bench marks established since the beginning of the survey is 4,160, which number does not include those bench marks of other organizations whose elevations have been determined by the Geodetic Survey of Canada.

Topography.—Very important topographic work was undertaken in 1913-1915 by the Geodetic Survey in the prosecution of a topographic survey of the Thirty-One Mile Lake Watershed and along the Gatineau river, in the interests of "A Pure Water Supply for a Proposed Federal District of Ottawa."

Preparations were also made for the organization of a City Mapping Division of the Geodetic Survey, to co-operate with the Civic Improvement League of Canada, but the prosecution of the required surveys was postponed until after the war. We are now making a large engineering topographical map of the City of London.

War Work.—After the outbreak of war in the fall of 1914 the Geodetic Survey party, in charge of the writer, was glad to be able to render some assistance to the Naval Authorities in the vicinity of Prince Rupert, B.C., in establishing signal stations.

German cruisers were in the immediate vicinity of that place and, as the Geodetic Survey had parties on prominent points of outlying islands, the communication of these points with Prince Rupert was of the greatest possible service in keeping the authorities there acquainted with what might be transpiring on Hecate Strait and Dixon Entrance.

Verbal thanks for services rendered was given the writer by Commodore Hose, of H.M.C.S. *Rainbow*, and a letter was sent to the late Dr. King, then Superintendent, expressing the thanks of

Lieut.-Colonel C. W. Peck, Commanding the 68th Prince Rupert Light Infantry.

The Towers of the Survey

The visible signs of the Geodetic Survey triangulation consist of skeleton-like towers so common throughout Ontario. These have caused many questions through the localities in which they are built. They are placed on the highest points within a radius of several miles.

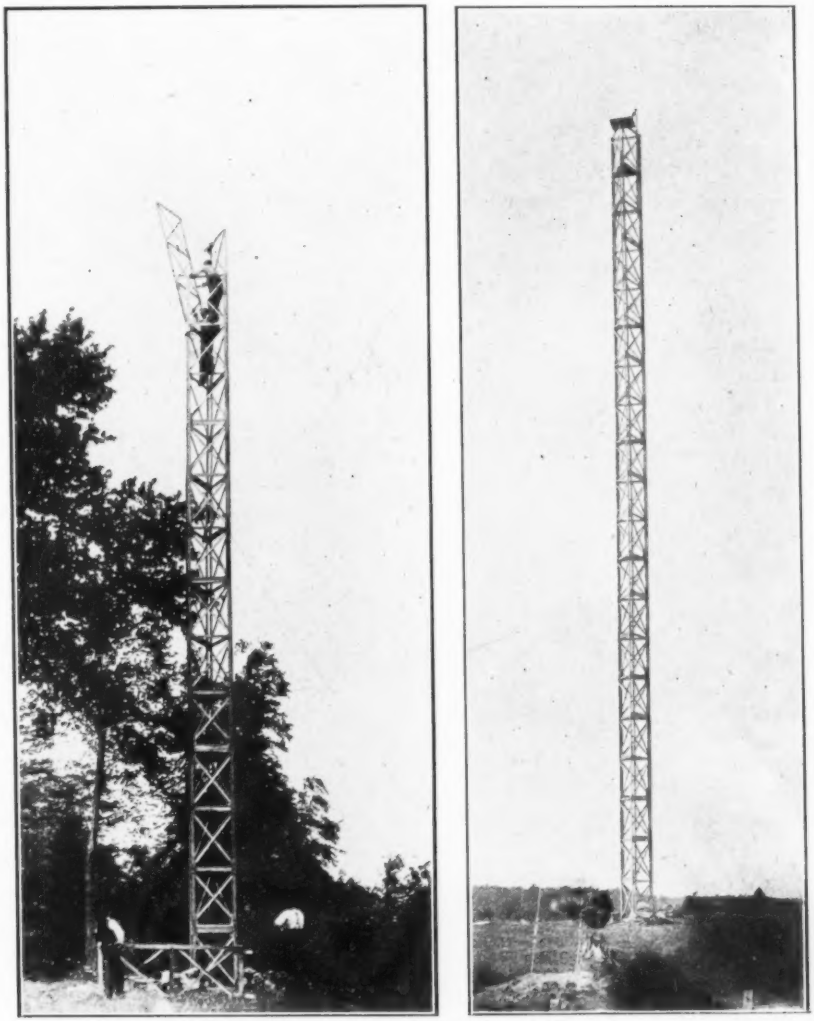
These stations must be visible one from the other. They form the angular points of a system of traingles over the country. The angles of these triangles are measured with a very precise instrument. When the distance between any two stations has been measured the accurate distances between any other two stations may be determined by computation much more economically than by any system of measurement, and much more accurately than by any but the most costly methods of measurement.

Thus a system of accurately defined points is provided for the surveyor or engineer who makes topographic, hydrographic, or other maps, and, since the positions of land survey posts close to the triangulation stations are always determined where possible, the relation of previous land surveys with respect to one another and to subsequent surveys is obtained.

Each of the points is permanently marked by a tablet set in a concrete block or in solid rock. Over each one of these points is erected a pier or stand if on a mountain peak, or a tower if on a wooded hill or in a flat country. These stands and towers are accurately centered over the tablet in the concrete or stone monument. The next step in the process of carrying on triangulation is to do the actual observing of the angles between each two points visible. In this way a series of spheroid triangles is formed.

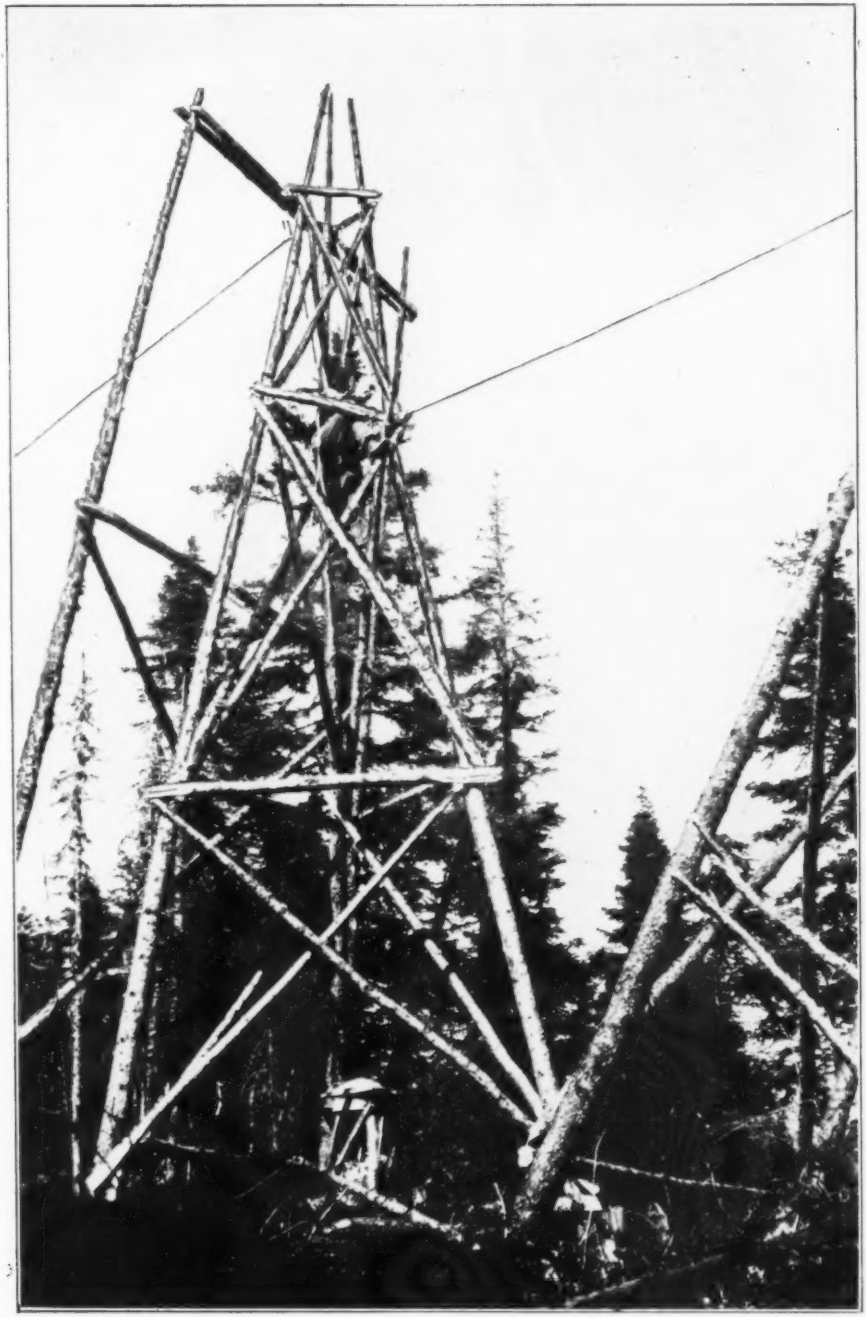
It is most important that primary triangulation be connected with all of the provincial boundaries in this country in order that there should be known the latitude and longitude of the boundary monuments. This will make it possible in the future to relocate any monuments that may be destroyed, thus avoiding long and expensive litigation over the boundaries of contiguous provinces.

The advantage of having a primary triangulation covering the

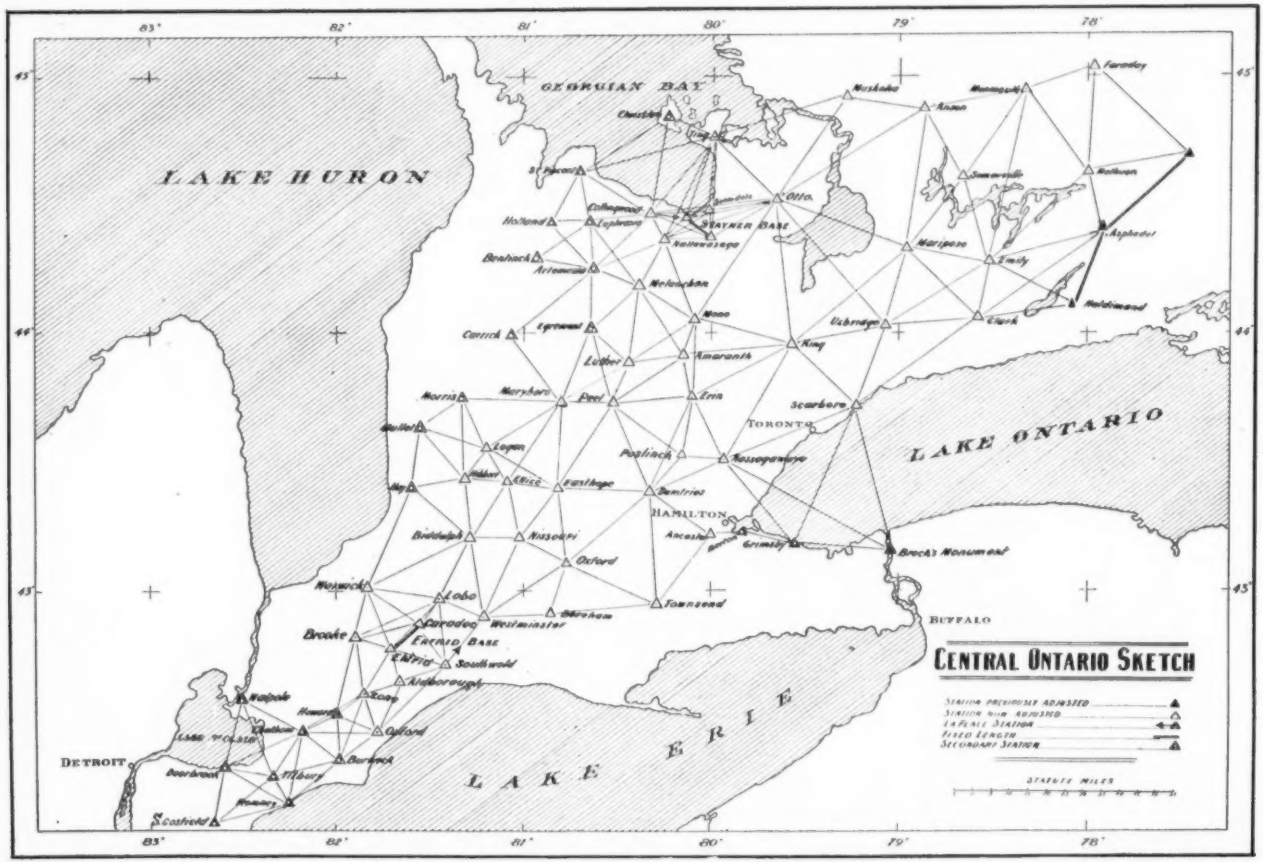


Portable Reconnaissance Tower, in course of Erection and Complete.

147-foot Tower, near Chatham, Ont., with Lamp-stand extended 37 feet.

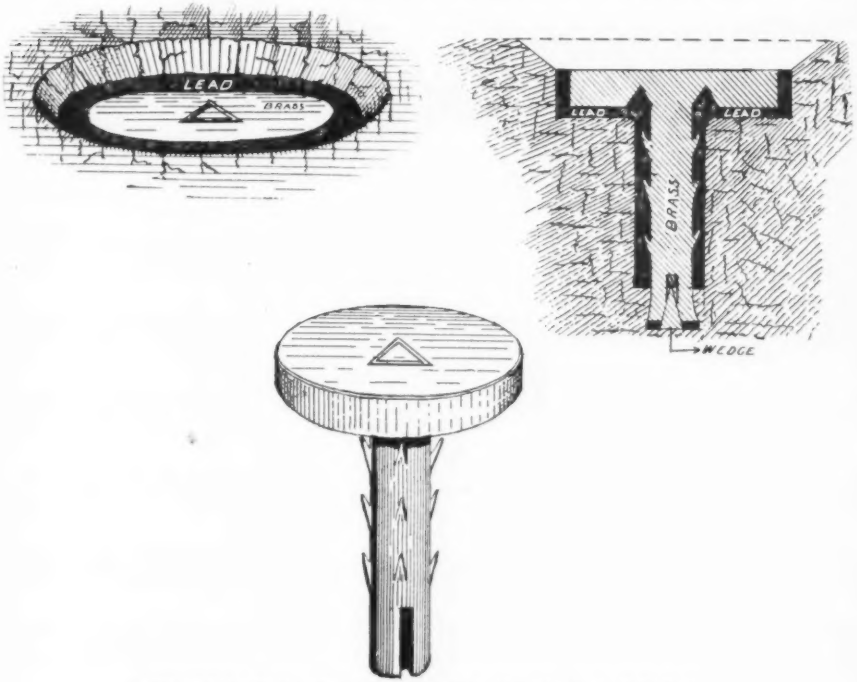


Rough-and-Ready Tower Building in Eastern Quebec, for sighting over Local Timber.



Map showing Location of Towers and Base-lines in Central Ontario.

whole country is very great, for it enables engineers and surveyors to co-ordinate all of the public and private surveys throughout the country. It is also important that a whole continent be covered by a continuous network of primary triangulation all based upon the *same initial point* in order to avoid the errors due to the deflec-



Triangulation Station Mark, showing Method of inserting in the Solid Rock.

tion of the plumb line at the various stations. This starting of all surveys from the *same initial point* on the same spheroid, brings into play what is known as the North American Datum and which I will explain as follows:

Early in the year 1913 a conference took place between the Superintendent of the United States Coast and Geodetic Survey, the Superintendent of the Geodetic Survey of Canada, and the

Director of the Mexican Geodetic Survey. The two latter adopted what was then known as the United States Standard Datum as the datum for their respective surveys. It was also agreed that, as heretofore, the Clarke spheroid of 1866 would be used by all three organizations.

On account of the international character of this adopted datum, the name was changed from the United States Standard Datum to the "North American Datum."

This decision to adopt the North American Datum as the datum for the results of the Geodetic Survey of Canada was such an important one, and so far-reaching in its effects, that it demands some explanation.

After the errors of a triangulation system have been adjusted the resulting angles and the distances between stations are used to compute the latitudes and longitudes of all the triangulation stations. These computations must be started from a station at which the latitude, longitude, and the direction to some other station are known. Also computations must be based on certain dimensions for our spheroidal shaped earth. Then the datum for the geographical co-ordinates (latitude, longitude and azimuth) throughout that system of triangulation is the position of that system on the particular sized earth which is assumed to be the correct one, and is defined by the co-ordinates of the station from which the computations started.

Thus the selection of a datum depends on a *balance* of Astronomic and Geodetic results. These astronomic results are, however, subject to errors which may be many times the errors of observation. They are due to the deviation of the plumb line at the points of observation, caused by the attraction of unequally distributed densities, such as mountains, lakes, valleys and subsurface dense masses. The triangulation in Canada had to be started at widely separated points. If a different datum were used at each of these starting points, and if one of these did not accord with the others, the triangulation based upon it would be twisted. Serious overlapping would occur where the different systems were joined.

That these discrepancies might be serious may be seen from the fact that astronomically determined positions may be in error by

as much as half a mile due to the deviation of the plumb-line as outlined above.

Thus it will be seen that it is necessary to establish a datum which is very close to the truth. The only method by which a correct datum may be determined is to have *very many* astronomical stations scattered over the country and to have them connected by triangulation. By this means the anomalies due to the deviation of the plumb line may be detected. The *most probable* position of the initial point to which the whole triangulation is fastened, and by which the position of the triangulation is governed, may thus be determined. It may easily be realized that thirty or forty years might elapse before a final datum could be selected for Canada.

Thus was the United States Standard Datum determined after years of effort. Some 600 astronomical stations have been connected by triangulation, and the whole system of the United States Coast and Geodetic Survey has been based on this one datum. At many points the stations of the United States Coast and Geodetic Survey are available for use in building and correcting the triangulation of the Geodetic Survey of Canada, and very wisely, it is felt, the late Dr. W. F. King, then Superintendent of the Geodetic Survey of Canada, in 1913 adopted the North American Datum as the basis for the Canadian triangulation, thus saving much time and money to this country in having the question of the datum for the Geodetic Survey of Canada settled for all time, and avoiding clashes between the results of surveys in this country also between those of Canada and the United States.

One might think that when the primary triangulation controlling the positions along the Atlantic coast, the St. Lawrence River and the Pacific coast is complete, and when the primary triangulation which has been extended across the country to join the Province of Nova Scotia with the Province of Ontario is extended across Canada to join the Pacific Coast triangulation, that the geodetic work of the Geodetic Survey of Canada would be finished. *This is largely true*, but when we meet the demands of the Survey for controlling the charts along the coasts, it will be found that there is hardly an area of any size in the interior of the whole Dominion that is not dependent on geodetic control for maps and surveys. For a number of years this Survey has contemplated extending an

arc of primary triangulation across Canada between the Pacific and the Atlantic Coasts. Its present plan is to extend rapidly the triangulation in order that there may be no place in settled districts more than about 100 miles from a primary triangulation station. There will be many parts of the country where the distances to primary triangulation stations will be much less than this.

The survey must also extend arcs of primary triangulation throughout the area of British Columbia and the Yukon Territory. This area extends from the vicinity of the Straits of Fuca to Dixon Entrance, and from the head of Lynn Canal to the intersection of the Yukon River and the one hundred and forty-first meridian of longitude. This meridian is the boundary between Alaska and Canada. The United States Coast and Geodetic Survey plans to extend their primary triangulation from Dixon Entrance to the head of the Lynn Canal along the Alaska Coast, also to extend their primary triangulation from the vicinity of Tacoma, Washington, to our primary triangulation in the vicinity of the Straits of Fuca. The Geodetic Survey of Canada and the United States Coast and Geodetic Survey would thus co-operate in connecting Alaska, the Yukon Territory and British Columbia with the North American Datum.

In the summary of work done by the Geodetic Survey of Canada I have mentioned the parts of Canada where Precise Levelling has been done, and the number of miles (14,031) of such lines of level.

While every one will agree that it is necessary to know the elevation of the ground in many of our daily occupations, it has not always been recognized as essential to have elevations at each place referred to the same surface or datum. For instance, in the past, two cities not very far distant from each other may have had different datums on which their elevations were based. One may have been the surface of a lake near it, the other an arbitrarily assumed elevation for a bench mark. At the present time, in most cases, mean sea level is used as the datum for elevations. This datum has been adopted by the Geodetic Survey of Canada and by *them* transmitted to other surveys. The Geodetic Survey will, no doubt, transmit in the very near future this Mean Sea Level Datum to all cities, provinces and private corporations, for this trans-

mission of aid is part of the work and duty of the Geodetic Survey of Canada. With such transmission clashing of arbitrary datums will vanish.

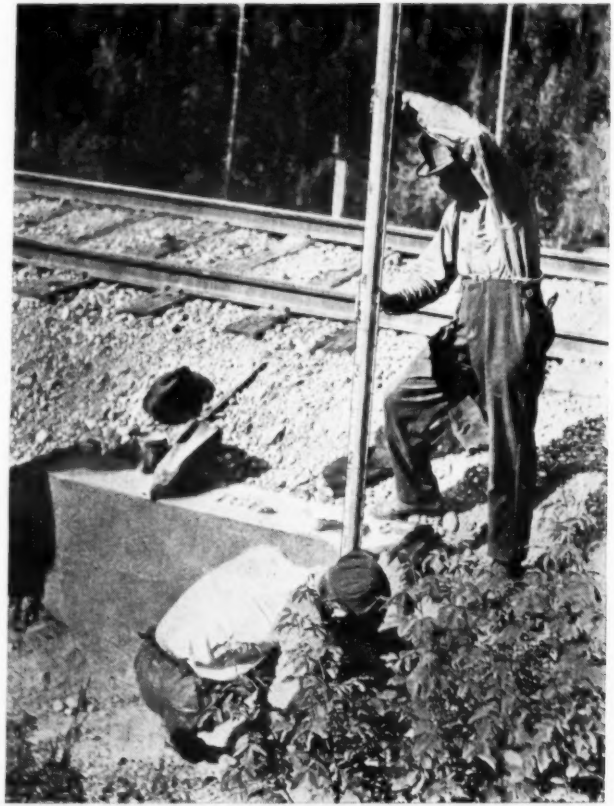
Mean Sea Level is the only datum that is a universal one; that is, it is the only datum that may be used for many detached pieces of levelling at different parts of our coasts. For instance, mean sea level may be determined at Vancouver, B.C., by tidal observations, and at Prince Rupert, B.C., and levels started from each, and on the Atlantic Coast at places like Halifax or Father Point. There is no limit to the number of places along the coast whose mean sea level may be called zero for any line of levels running inland. When levelling has been started at a number of places along the coast and lines extended inland from them, it is reasonably certain that when these lines join in the interior of the country the elevations of a common point, as given by the several lines, will agree almost exactly. Of course each determination at this point will be subject to the unavoidable small errors incident to the precise levelling.

Precise levelling is, wherever possible, carried on along railway tracks rather than along highways or across country, and bench marks are established every three or four miles, also in all cities and towns through which the lines pass.

The standard bench mark established by the Geodetic Survey consists of a copper bolt ¾ inch in diameter, stamped on the end with the letters "G.S.C., B.M." (Geodetic Survey of Canada, Bench Mark). It bears a horizontal cross-mark upon which the elevation is taken, and its number is stamped upon it. Properly put in, it is impossible for any one to remove it without destroying the surrounding rock or masonry. Elevations are not stamped on the bolts because the elevation of a bench-mark in a precise levelling net may not be finally determined for a long time. The closing of circuits and introduction of new cross lines will call for adjustments which will make changes of greater or less magnitude in the elevations.

The primary triangulation and the precise levelling that have been done are excellent in quality and form the basis from which other primary triangulation and precise levelling may be extended. We should probably have as much more primary triangulation and

Ready to Observe, on a Mountain Top in British Columbia.



Bench-mark in a Culvert under the Canadian Pacific Railway near Field, B.C.

precise levelling done in the very near future as there is now in existence. It is all the more necessary that this work be extended very rapidly on account of the great development that is going to take place from now on in the industries and commerce of the country, and especially in the extension of its roads, railroads, river control, and other public works. Hundreds of thousands of dollars are expended on roads alone each year in Canada. Each road that is built within an area not covered by a topographic map

Bench-mark at the Entrance to a Tunnel on the Grand Trunk Pacific Railway near McBride, B.C.

costs more in labour and material than if a topographic map were in existence. It may be said that this applies to all extensive pieces of engineering work. In order that the topographic mapping of the country may be done accurately and economically the primary triangulation and precise levelling should be *rapidly extended* into those areas that are to be mapped.

The lack of sufficient geodetic work in the form of primary triangulation and precise levelling is not due to negligence on the part of any one, for it is only recently that engineers and surveyors

have recognized the necessity for this geodetic control of maps and engineering work, and have made heavy demands upon the Geodetic Survey of Canada to furnish it. With increased demand upon the Survey for this control it is naturally to be expected that funds will be provided to meet such needs.

It is the policy of this Survey to publish only *final* data with regard to the triangulation, but many requests for information regarding the geographical position of points, where the need of such data is great, have been met by providing preliminary values in the meantime. These preliminary values may depend on only part of the field data secured, and are hence only approximate, but they may be very close to the final values and may meet immediate demands.

The triangulation data of the Geodetic Survey has been used by several departments of the Government as well as others. It is to be pointed out that the information available has been only a part of that requested, and this Survey finds itself constantly behind in the matter of providing information as it is needed.

The Departments to which information has been given are:

1. *Militia Department.*—Triangulation data in Quebec and Ontario to control the accuracy of the Military topographic maps.

2. *Naval Department, Hydrographic Survey.*—Triangulation data at many points along Lake Ontario and the St. Lawrence river, and on the British Columbia coast, to control the accuracy of hydrographic maps.

3. *Interior Department, Chief Geographer's Branch.*—Triangulation data at many points scattered over Ontario and Quebec for the purpose of controlling the accuracy of the compiled topographic maps of that branch.

4. *Department of Mines.*—Data in various parts of Canada.

5. *Department of Public Works.*—International Boundary Surveys for the control of their surveys.

6. *Quebec Streams Commission.*—Field work was undertaken and preliminary results supplied to control the accuracy of their surveys.

7. *Triangulation schemes* have been based on the primary sets in the vicinities of large cities and industrial areas. Such areas include Halifax, N.S.; St. John, N.B.; Montreal, Que.; and

London, Ont.; and Vancouver and New Westminster, B.C. Other areas will be added to these as requirements demand.

Furthermore, attention is directed to the fact that publications have been issued from year to year for several years past giving full results of the field work. These publications have been distributed amongst all parties known or presumed to be interested in the results in each district covered. It is undoubtedly true that many persons who otherwise would have made specific requests for information have been content to wait for such information to reach them in printed form. This applies with especial force to the several railway companies over whose lines the work has been prosecuted, who, by the terms of their agreements with the Department, are to be furnished with descriptions and elevations of all bench marks established on their property.

Technical Publications

From time to time, as material is presented, it is the intention of this Survey to issue publications of a technical nature which will contain:

(1) All the data made available by the operations of the Survey.

(2) Geodetic and topographic methods of both field and office work.

Only by the publication of investigations on these subjects can the work of this Survey be made useful in advancing the state of theory and practice among those doing similar work.

When this great work is more widely understood in Canada its uses will be unlimited, and we may confidently expect an enormous saving of money and labour to public and private interests.

RAINMAKERS AND RAIN

By J. Patterson

Medicine, Religion, Astronomy and Meteorology are probably the oldest subjects of study and observation, and date from the very earliest beginnings of civilization. By the time Babylon had reached the height of its power these were all grouped under Astrology, and most of the weather proverbs, superstitions and charms had their origin in these far-away times. Fortunately, most of the superstitions and medical charms have disappeared, but the weather proverbs still survive. We still have many newspapers that publish weather forecasts based on these same methods of prediction, and also rainmakers who think that Old Mother Nature gets sick at times and requires their particular brand of medicine; one in particular thinks that all she needs is to have dust thrown in her eyes and she will then function properly. These men may deceive themselves and some of the people, but they will not deceive Old Mother Nature. She will go on her way performing her duties regardless of what they may do, and men will have to conform to her ways, not she to them.

No doubt many still think that Meteorologists will not adopt their methods through ignorance or jealousy because they are not of the scientific class. No! these are not the reasons. Meteorologists are scientifically trained men and they adopt scientific methods to study the weather. They would be the first to adopt any method that was successful in producing rain, if that were possible, or of improving the forecasts. They have examined all the methods and as none of them will stand the test they have been rejected.

Science aims always to discover truth and refuses to believe that things happen by chance, that the workings of Nature are mysterious and past finding out, that she is controlled by mysterious laws, or that she is dependent on the whims of spirits of good or evil repute. Science knows positively that rainfall is absolutely beyond

the control of man. You will naturally ask what is your proof before we can be expected to accept such a strong statement; the object of this article is to attempt to set forth in simple language the scientist's reasons for his assertion.

The scientific man believes that a definite set of conditions will always produce the same result. For example, you know perfectly well that if you were to sow a field of wheat, and if it got no moisture of any kind, the grain would not sprout, or, if it did, it would soon wither and die; or, again, if the field consisted of pure sand without any fertilizer the wheat would also perish. If any one asked you what would happen under these conditions you would say at once from your knowledge that these causes would produce crop failure. Why do we not have men who can make wheat grow under the above circumstances by performing hypnotic tricks to deceive Mother Nature, or by enchantments cause it to spring forth and grow? It is simply that there is no money in it, for everybody would think that the only safe place for such a one was the lunatic asylum, yet it is not a bit more difficult to do this than it is to assist in producing rain. In the latter case the rainmakers are simply dealing with causes that are not understood by those who have not made a study of them.

Dry air consists of about 79 parts of nitrogen and 21 of oxygen, with a little carbonic acid gas; these amounts are constant the world over, but in addition there is water vapour which is very variable. Water covers three-fourths of the surface of the globe and is known in three different forms: ice, water and vapour or steam. It is always present in two forms at least; if it is very cold we have ice and vapour; if warm it exists as water and vapour, while at times there may be all three. The amount of water-vapour in the air is much greater when warm than when cold. This is because there is a definite amount of vapour that can exist in the air for each temperature: thus, at zero the air can hold only 1.1 oz. of vapour, at 32 degrees 4.8 oz. and at 60 degrees 12.7 oz. in 1,000 cu. ft. When the air has all the moisture that it can hold at that temperature it is said to be saturated, and if it were cooled it could no longer hold that amount and the excess would be deposited as cloud, fog or rain.

When a heavy fall of rain occurs a very large amount of moisture

is taken out of the air, and unless there is some agency for replenishing this loss there would soon come a time when there would be no more moisture left that could be precipitated as rain, and drought would follow over the whole world. Nature has, however, provided the means whereby this loss can be made good and that is by evaporation. No matter how cold it is there is always some evaporation going on from the surface of the snow and ice, but the amount is very small; the hotter it is the faster the evaporation, and consequently the great storehouses for replenishing the vapour in the air are the oceans, especially in the tropics. Having located the reservoirs, the question arises, how is the water transported from the fountain head, where is the pipe line that can have so many ramifications as to spread itself over the inhabited world? The pipe lines are the winds and he who can control the winds can control the rain. Then what controls the winds?

You know that you can pump water from a well if the sucker is less than 33 ft. above the top of the water, but if it is at a greater height it will not bring up the water, because the air will not force the water up in the pump higher than 33 ft. The pressure of the air will thus support a column of water 33 ft. high, and this tells us that as the air can just balance a column of water 33 ft. high the weight of the air in a column of air extending right up to the top of the atmosphere and of the same cross section as that of the water in the pump must be the same as the weight of a column of water 33 ft. high. This weight is about 15 lbs. to the sq. inch cross-section at sea level. In other words, air has weight the same as any other substance, as iron or wood. This is called the pressure of the air, and it is because of this pressure that birds and air-planes can remain in the air by flying through it. It is also due to this that winds exist and transport the moisture from place to place. When the pressure is measured at different places over the surface of the globe it is found that it varies from place to place; in some regions it is higher than at other places and this causes a flow of air from the place where the pressure is high to the place where it is low, just as the water in a river runs downhill and not up, or it flows from the higher pressure head to the lower. Again the greater the fall a river has the faster it will flow, and in places where the fall is very great it may be a raging torrent, while if the river has very little

fall the current will then be very slow and sluggish; just so with the air, if the fall of pressure is great the winds will be very strong, while if the fall of presure is very little the winds will be gentle or there may be a calm.

By plotting the pressure at different places on a map of the region it is found that these places of high and low pressures have very definite forms, with a very definite wind circulation around them. It is also found that these systems travel, sometimes fast and sometimes slow. Again it is found that generally the weather is fine and clear when the pressure is high and that it is stormy and wet when the pressure is low, or in other words, all our storms are associated with the low-pressure systems. Generally to the east of the north-and-south line through the centre of the low the weather is warm, moist, cloudy and at times wet, while to the west the weather is clearing and the winds are often very strong from the west or northwest, with rapidly falling temperature. It is the movements of these "lows," as they are called, that bring the rain and snow. Whether a place will receive any rain during the passage of a low depends on its position with respect to the centre of the low.

The above is a short statement of how the rain is brought to the place and now comes the great question: how is the vapour to be condensed into rain?

According to some reports, the rainmaker maintains that there are not enough dust or electrified particles in the air on which the moisture can condense, and if more were added it would produce more condensatoin, and thus give more rain or else some rain when none would otherwise fall. One would have supposed that all the cannonading, all the various gases of every description and all the electrified particles produced by high explosives that were thrown into the air during the great battles on the Western Front during the War would surely have produced some effect, if anything would, and yet there is not the slightest indication that they had any effect whatever in producing rain.

There is an idea that the vapour in the air cannot return to the liquid condition unless there are dust or electrified particles present on which the vapour can condense to form drops. Now this is a very interesting question and deserves consideration, for it is

true that particles are of material assistance in enabling the vapour to condense. It was first shown by Aitken, of Edinburgh, that if you took a quantity of saturated air and expanded it suddenly in a cloud chamber to produce cooling, that a dense cloud was formed, and if the same sample of air was expanded several times that the cloud was less and less until it was impossible to get any cloud with this same degree of cooling, but it was always possible to get a few drops. If now dust or smoke was introduced into the cloud chamber the cloud would immediately form as at first, and this method is used to count the number of dust particles in the air. Later C. T. R. Wilson found that the same result could be obtained by putting electrified particles into the air. It was also noted that when the particles were very few that the drops produced were quite large. In all these cases the air was saturated with moisture at the beginning and it was found that the vapour would not condense on the particles until it was sufficiently cooled to give 3- or 4-fold saturation when fog appeared, and the fog particles grew rapidly in size until the air was brought back to saturation for that size of drop. The experiments also showed that the fewer the particles for the same amount of moisture the larger would be the drops and the faster they would fall. All water drops fall at a rate depending on the size of the drop, and so definite is this that by observing the rate at which they fall, and knowing the weight of water produced, it is possible to calculate the number of drops of water and their size.

Fog particles are about 1/2500 of an inch in diameter and fall 7 inches a minute; light rain drops are 2/100 inch in diameter and fall 400 ft. a minute; in heavy rain the drops are 6/100 inch in diameter and fall 1000 ft. a minute.

This leads to some interesting speculations about the amount of rainfall obtainable from a cloud. It is of no use to have the vapour condense and form a cloud, for the fog particles are so small that they would never reach the ground, seeing that they fall only 7 inches a minute. As already stated, the size of the small fog particles is only about 1/2500 inch in diameter and in 1000 cu. ft. of air filled with fog particles there is obtained 1/150 ounce of water; the number of drops in this volume is about 420,000,000. If now they could be induced to grow to the size of large rain drops 6/100

inch diameter they would yield 24 cu. ft. of rain, or by taking a column 10 ft. high and a base 10 ft. square it would give 2.88 inches of rain; if the column was 1000 ft. thick or high, as many clouds are, it would yield 288 inches of rain; by that time one would not care to be responsible for the life of the rainmaker. These figures simply show that there are in the air always far more than enough particles on which the vapour can condense, and that it is not more particles that are required to get the rain; in fact it would appear that the proper course to pursue would be to get most of the dust particles out of the air, so that there would be only a few on which the vapour could condense and thus produce large drops that would fall. Could this be done there would, undoubtedly, be rain drops form, but they would never reach the ground as they would evaporate as soon as they came in contact with the unsaturated air below the cloud level.

But some will say that after the fog particles form they will unite to form large drops and thus get to earth; in this case, however, the rainfall would be insignificant, amounting to only 2/3 oz. from a cloud base of 100 sq. ft. and 1000 ft. high, or about 1/100,000 of an inch; a sprinkling-can would surely be more efficient. Further these small drops do not, as a rule, unite to form large drops. Something more than the number of dust particles in the air and the amount of fog produced when cloud is formed are required to produce rain. Then what is it?

Some say that the rainmaker is going to release some cooling gas, such as ammonia, into the air and that will set the machinery in motion. They are quite enthusiastic over the prospect for do they not see time after time about the sunset hour the dark, heavy rain-laden clouds appear over the foothills of Southern Alberta and —at last all expect the long-looked-for rain—but only to have their hopes vanish with the passing cloud. "If now some cooling gas could only be added to bring down the rain the district would be saved. For instance, take a room full of steam, would it not be possible to release a gas with cooling properties in it which would cause immediate condensation of the steam? Then, why not attempt it on a larger scale and release a liberal quantity of it in a heavy cloud area, and it seems reasonable we should get rain as a result; and if the gas was powerful enough to penetrate through

the cloud we should get the benefit of all its moisture." Yes, it would be a comparatively simple matter to inject some gas with cooling properties into the room to cause immediate condensation of the steam, and as the possibility of doing the same thing on a larger scale in the clouds has been raised in all seriousness, it merits careful consideration, especially as one can realize somewhat the anxieties of those in regions that have a precarious rainfall. The question must be considered in the same way as any other engineering project and an estimate made of the magnitude of the operation before it is possible to form any idea as to its feasibility.

The first question is, what are the cooling gases and what are their properties that make them distinct from other gases? Why, they will say that ammonia is used in refrigerating plants for making ice; it must surely be a cooling gas. Then there is carbon dioxide; it is also used for the same purpose. If these cooling gases are let loose in the cloud surely they will cause the cloud to rain. These gases must do one of two things, either they must dissolve in the water vapour and so make it condense, or they must simply cool the air. Some gases, as ammonia, dissolve readily in water, but they do not dissolve in the vapour; if any gas attaches itself to the vapour it will form a new substance and disappear as water; that would be a very effective method of preventing rainfall. The only action then that these cooling gases could have would be to produce artificial cooling of the air and thus condense the moisture in the air.

No gas in itself has any cooling properties distinct from any other gas, and ammonia in this respect is no different from oxygen or nitrogen of the air, but it is used in refrigerating plants because it can be turned into liquid ammonia by pressure at ordinary temperatures; when the pressure is released the liquid evaporates rapidly and freezes the water. But any other gas will do the same thing at certain temperatures. Air can be turned into a liquid (this is the cheapest way of making oxygen at the present time) at a temperature 300 degrees below zero. Liquid air would surely be the ideal substance to get into the cloud for it could very easily be carried by air-plane and scattered through the cloud; it would freeze all the vapour out and then the ice would melt by the time it reached the ground and thus you would get rain—but what about the cost?

This method of causing rain by cooling the air simply resolves itself into finding how much cooling would be required to condense

the vapour to give whatever rainfall was desired, provided the moisture was there. Some of the large refrigerating plants, by using 1,000 horse-power installations, can freeze 400 tons of ice per day. Freezing 400 tons of ice requires the same amount of heat to be taken out of the water as condensing about 55 tons of vapour to water. One inch of rain on an acre is equal to 113 tons of water, and consequently it will require about 2,000 h.-p. for a day to give an inch of rain per acre. As the contract calls for 2 inches of rain to be credited to the rainmaker on an area of 100 mls. radius (nearly 20,000,000 acres) it would require 80,000,000,000 h.-p. for a day, or as it has to be done in about 100 days it would require an 800,000,000 h.-p. refrigerating plant to produce sufficient cooling to condense the moisture without considering the cooling of the air that would also be involved. Comment is hardly necessary.

Let us turn now from the ways of man to those of nature and let us see how she produces rain.

As already stated, the water supply is maintained by evaporation from the great water surfaces of the globe and you know that if you want to turn water into steam it is necessary to supply heat to the water; it is also just as necessary to supply heat to evaporate it and it requires the same amount. To evaporate enough water to give an inch of rain on an acre requires all the heat that can be obtained from the burning of 8 tons of coal, or for a 4-inch rainfall on an area of 100 mls. radius, 640,000,000 tons of coal. Truly an immense amount of heat to do the work of evaporating, but then, as this amount of heat was supplied to the water to turn it into the form of vapour, it will be necessary to take this amount of heat out of the vapour before it can be turned into water again. An operation of such magnitude that it is utterly beyond the power of man to attempt. But you may say that it is impossible for nature to evaporate so much water; where can she get enough heat to do this. Observations on the heat given out by the sun show that it is sufficient to evaporate enough water to give an annual rainfall of 40 inches over the entire globe and still have some to spare.

It has been shown that there are more than enough dust or electrified particles in the air to permit the condensation of all the moisture that is required. Clouds exist for days without any rain falling and it is seldom that rain of any consequence falls from heavy fog or mist. Something more than the number of dust particles

in the air and the amount of fog produced when cloud is formed are required to produce rain. Then what is it? Evidently something that will make many of these small particles grow to the size of rain drops. It has been proved many times by experiment and mathematical calculation that the larger the drop the easier it is for vapour to condense on it, and consequently the air does not require to be so highly supersaturated after the fog particles have formed as just prior to their formation on the dust speck; from this on the dust and electrified particles probably take no further part in the process of rain making. Moreover the moisture will soon condense on these little fog particles and there will thus be no more moisture to come from the air; then what is to be done to get the drops large enough to fall; obviously there must be more vapour obtained from somewhere before this can happen. Here is seen one of the great wonders of nature for the machinery she now sets in motion is so simple and yet so stupendous in the force that it exerts that one can only say "man can have no part in all this glorious work." First, nature has to compel the vapour to give up the heat that was stored up in it when it was evaporated, for until this heat is taken out it is impossible for the vapour to be turned into rain. That means that the vapour required to give a 4-inch rainfall on an area of 100 mls. radius must yield up the heat that was equivalent to the burning of 640,000,000 tons of coal which were required to evaporate the water in the first place.

The method by which the vapour has been brought to the place where it is to be deposited has already been described. Generally to the east of the centre of the low pressure area the weather is damp and warm and is forced to rise by the pressure distribution. As it rises it is cooled and when it reaches the cloud level it is saturated, so that when it passes up through the cloud the moisture is condensed on the fog particles already there and these grow rapidly in size; as they grow they fall faster, thus coming in contact with more saturated air. By this time they have become fair-sized drops and fall as rain. The rain will continue just as long as the cloud is fed with saturated air, but as soon as the supply of saturated air stops the rain will cease. This, then, is briefly the mechanism that produces rain. Of course there are other methods whereby the cooling can take place, such as warm currents of air meeting cold currents, but all the other methods are insignificant

compared to the first. Some idea of the volume of air required to yield up its moisture to give a fall of 4 inches of rain on a radius of 100 mls. may be gained from the fact that if the air is saturated at 60 degrees and is then cooled 10 degrees to 50 degrees, the air current would have to be 2,000 ft. thick, 200 mls. wide and 3,600 mls. long.

Southern Alberta is just to the east of the mountain barrier that shuts off the warm moisture-laden winds of the adjacent Pacific and it probably derives almost all of its moisture from the tropical oceans. Most of the storm areas pass either to the south or north of the region, and so Southern Alberta is not in the usual track of these storm areas. She thus receives rain from only the occasional storms that cross the area, and it is due to this that the rainfall of Southern Alberta is so precarious.

Some say, in these days, that there are reports on stream measurement, irrigation projects, soil survey, etc., but nothing is being done about investigating the atmosphere; if meteorologists would only attempt such an investigation they would make some wonderful discoveries. Meteorologists have not been negligent, as some would suppose, and have been carrying on their investigations for many years and have found out many wonderful things about the atmosphere but they are beyond the scope of this article. Suffice to say that when some men point to all the wonderful discoveries and inventions during the past forty years, such as the air-plane, the submarine, wireless telegraph and telephone, etc., as evidence that man can also have dominion over the clouds if he will only exert himself, forget that these inventions have not changed the course of nature; they have not altered the movements of the sun, earth and planets; the seasons still come and go with the same regularity and the weather still shows the same vagaries as of yore. Over these man can have no control.

The only means that man can adopt to prevent crop failure in regions where the rainfall is precarious is irrigation, if the water supply is available. The energy involved in this operation is trivial compared to that of changing the water from the liquid condition to the vapour condition or *vice versa* as nature has to do in order to bring rain.

Meteorological Office,
Toronto.

THE CYCLE OF JUPITER AND SATURN

The noteworthy character of their conjunction in September, and the cycle of their conjunctions in relation to the Zodiac.

By W. Bell Dawson

The conjunction of Jupiter and Saturn, which will occur in September, is very noteworthy, because it takes place at the equinox when the sun itself is there; and it also occurs at a point in the sky which appears to have been the original starting-point of the signs of the Zodiac, when these were first devised. It may thus be considered as the end of a cycle of very long duration, extending over most of the human period.

The autumnal equinox, in our time, is between the constellations Leo and Virgo, and the sun will be close to the position of the planets at their conjunction, which takes place very near to the equinox. The occurrence will thus be invisible, although it becomes all the more remarkable as a coincidence. It is also to be remembered in dealing with the Zodiac that the meaning of its signs in relation to the seasons of the year were based by the Ancients on the position of the sun itself in the successive constellations month by month; and not on what is visible at the time.

The two planets are now (in April) at the eastern end of the constellation Leo and are conspicuous in the evening sky. By September 22nd Jupiter will have come up to Saturn, and the sun will be in conjunction with both of them and close to the equinox at the same time.* This occurs almost on the meridian of the star Deneb, the extreme end of Leo.

There seems to be no doubt that the line between the constellations of Leo and Virgo was the original starting-point of the signs of the Zodiac when they were first devised. This is commemorated by the Sphynx, which is in reality not mythological, but an astronomical emblem; as the union of the woman's head

*When the Sun passes Jupiter and Saturn, immediately before their conjunction, the three bodies are all within the limits of ¾ of a degree of Right Ascension.

and the lion's body represents the junction between the constellations of the Lion and Virgin. The Sphynx may also be taken as symbolizing the whole Zodiac, in beginning with the head of the Virgin and ending with the tail of the Lion; and it would thus indicate just as distinctly where the Zodiac was considered to begin and end. These questions are fully discussed in "The Witness of the Stars," by Dr. E. W. Bullinger.

The coming conjunction may thus be considered as taking place at the true starting-point of the Zodiac, as well as at the equinox and with the sun, as pointed out. On account of the rarity of such coincidences it seemed worth while to investigate the length of the cycle involved. The cycle arises primarily from the conjunction of the two chief major planets, and its period depends on the conjunction taking place at the same point among the stars. One of the two, Saturn, has the longest period of any visible planet, nearly 30 years; and it thus afforded to the Ancients the longest primary cycle known to them. Its name *Chronos* indicates this, as it is the basis of the term "chronology." Any cycle connected with Saturn which runs back into ancient times should thus be of special significance.

We give the calculation of the length of the cycle by itself, and afterwards some explanation of the result arrived at. The calculation may have some additional interest also in exemplifying a method of arriving at the value of a cycle.

Calculation of the Cycle

The sidereal periods of Jupiter and Saturn, as given in the *Annuaire du Bureau des Longitudes* for 1920, in Julian years, when reduced to the last reliable decimal, are as follows:
Jupiter, 11.86198 years.....Saturn, 29.45717 years.

The period from Conjunction to Conjunction is found from the formula, $a/1-r$ where a is the period of Jupiter, and r the ratio of the two periods which is 0.4026857. The result is

$$\frac{11.86198}{1-0.4026857} = 19.85886 \text{ years},$$

which we may term the Conjunction period.

It is not difficult to see that every third conjunction agrees fairly with the periods of the two planets, which gives a first approximation.

3 Conjunction periods = $3 \times 19.8589 = 59.5767$ years.

5 revolutions of Jupiter = $5 \times 11.8620 = 59.3100$ years.

2 revolutions of Saturn = $2 \times 29.4572 = 58.9144$ years.

The differences of these values will give the residual error after the three conjunctions, and dividing these residual differences into the periods of revolution will show how many conjunctions must occur to make up from the residuals one complete revolution of each planet. Thus:

Residual differences, $59.5767 - 59.3100 = 0.2667$

and $59.5767 - 58.9144 = 0.6623$.

Then, for Jupiter, $11.8620 \div 0.2667 = 44^{47}/_{100}$ times.

and for Saturn $29.4572 \div 0.6623 = 44^{48}/_{100}$ times.

Taking, then, 45 times the values in the first approximation, as the nearest whole number of times, and adding one revolution of each planet as indicated, we obtain a second approximation.

45 times the 3 Conjunction periods = 135 periods = 2680.952 years.

45 times 5 revol's of Jupiter + 1 = 226 revol's = 2680.812 years.

45 times 2 revol's of Saturn + 1 = 91 revol's = 2680. 605 years.

It is further evident that the half-time indicated by the fraction of a time above 44, can be eliminated almost wholly by doubling the above numbers, which will add two revolutions of each planet instead of one. A further approximation will, therefore, be obtained by taking twice 44½ or 89 as the number of times. The computation in this case is made with strict accuracy from the true values for the periods and their ratios as originally stated, which will make the third decimal place reliable.

89 times 3 Conjunction periods = 267 periods = 5302.316 years.

89 times 5 revol's of Jupiter + 2 = 447 revol's = 5302.305 years.

89 times 2 revol's of Saturn + 2 = 180 revol's = 5302.291 years.

As the periods and revolutions as thus determined can all be divided by three, a still more accurate value for a cycle one-third of this length can, therefore, be obtained.

89 Conjunctions of the planets = 1767.439 years.

149 revolutions of Jupiter = 1767.435 years.

60 revolutions of Saturn = 1767.430 years.

These successive results have been indicated as possibly of interest in showing the steps by which a cycle of such remarkable accuracy may be arrived at by ordinary arithmetic. The data do not admit of going beyond the third decimal of a year for the cycle.

As the cycle does not comprise a complete number of years the sun will not be in the same position at its beginning and end. To determine the sun's position correctly, relatively to the planets, or the season of the year at the beginning and end of the cycle, the actual length of the year must be taken instead of the Julian year of 365.25 days, with allowance for secular acceleration in the length of the year because of the great length of the period. The true length of the solar year at various epochs, back to 500 B.C., will be found in "Solar and Lunar Cycles implied in the Prophetic numbers in the Book of Daniel" by the writer. The nearest approach to an even year which these cycles afford is in the period of twice the last cycle or 3,535 years.

Significance of the Result

It is evident that if the two planets make an even number of complete sidereal revolutions during the period of the cycle, the conjunctions at its beginning and end will take place at the same point amongst the stars. The conjunction at the beginning of the cycle will, therefore, be on the line between the constellations Leo and Virgo, just as at the conjunction which takes place this year. This result is attained by the foregoing calculation, as the cycle contains an even number of revolutions of each planet. The differences of time between the sum of the revolutions and the cycle of conjunctions as arrived at, show that the planets are within one-eighth of a degree of the same position in Longitude at the initial conjunction as at this terminal one. The cycle indicates the long period that elapses between such coincidences.

In relation to history, if the coming conjunction (in September, 1921) is taken as the end of the longer cycle of 5,302 years, because of its occurrence at the primary point in the Zodiac as originally devised, the beginning of the cycle will fall in the year 3,382 B.C. This is about the date of the Deluge, according to those authorities who accept early chronology as given in the Septuagint, rather than

in the Hebrew text which they consider to have been tampered with later. There is some ground for this view, as the Septuagint translation was made from early Hebrew manuscripts about three centuries B.C. The date of the Deluge on the Septuagint reckoning is 3,332 B.C., and we mention this in the present connection as affording the only correlation with history that we could arrive at in relation to this long cycle.

It is known that the Zodiac had a very early origin, in the times of primitive man, as it is practically a common heritage of the human race; and if this cycle can correlate the positions of the planets, especially Saturn, with the choice of a starting-point in the Zodiac, it would be very interesting.

So early a date for the origin of the Zodiac may not seem too remote, when some authorities maintain that its starting-point, as described, was chosen because it then coincided with the Summer Solstice. The date on this supposition would be about 3,840 B.C. or five centuries earlier, as nearly as this can be computed from the precession of the equinoxes over so long a period, as the rate of precession is not absolutely constant.

Apart, however, from its historical interpretation the outcome of this investigation may be summed up as follows:

(1) One of the longest cycles in astronomy, based on the revolution of the two visible planets of longest periods, Jupiter and Saturn.

(2) A simple relation between the revolutions of these two planets, 60 revolutions of Saturn being almost exactly equal to 149 revolutions of Jupiter.

(3) In the period of the cycle, 89 conjunctions of these planets take place, with the initial and terminal conjunctions of the cycle practically at the same point in the heavens.

Ottawa,

25th April, 1921.

MEETINGS OF THE SOCIETY

AT VICTORIA

April 5.—The meeting was held in the Girls' Central School, the President, Mr. J. E. Umbach, being in the chair.

The following were elected members of the Society: Mrs. W. Monteith, Capt. P. Shadforth, Dr. R. E. McKeon, Messrs. D. P. W. Maunsell, E. A. Cleveland, A. S. Deanville, F. B. Gibbs; and Dr. J. Ewart Gee, of Fernie, B.C.

The President introduced the lecturer of the evening, Commander B. S. Hartley, who addressed the audience on "Modern Astronomical Navigation."

Commander Hartley first dealt with the importance of checking "D. R." (Dead Reckoning) by astronomical observations. He then took up the subject of geographical position of an observed heavenly body at the instant of observation, using black-board diagrams to illustrate his remarks. And finally he explained the uses of "Position Lines." It became obvious that by transferring he point in the heavens to its relative point on the earth the method of spherical trigonometry which would be applied by the astronomer would be replaced by a method of spherical triangles, a circle on the earth with defined centres and radius and observed zenith distance giving the place of the ship as on this circle. Commander Hartley demonstrated how the most probable position of the ship was the nearest point of the circle to the estimated position, the point called the "Position Point" being required to be laid down on the chart. This being done, the position line could be drawn for a short distance on either side of the position point by drawing a straight line through the position perpendicular to the bearing of the heavenly body observed. To find how far the position point might be away from the estimated position, the distance of this position from the geographical position of the heavenly body was calculated.

Dr. J. S. Plaskett, moved the vote of thanks to the speaker, this being seconded by Mr. G. S. McTavish.

April 26.—The last meeting of the spring term was held in the Girls' Central School, Mr. J. E. Umbach, the presidnet being in the chair.

The following question regarding Saturn had been asked and the answer to it was given by Dr. R. K. Young:

Question: Saturn appears very faint this opposition. Is this mostly due to the fact that the plane of the rings is passing through the line of sight at the present time? In 1917 the mag. $= -0.1$; in 1921 mag. $= +0.9$.

Answer: Yes. The brightness of Saturn depends on:

(1) The phase of the central ball; (2) The distance of Saturn from the sun; (3) The distance of Saturn from the earth; (4) The inclination of the plane of the ring to the earth; (5) The inclination of the plane of the ring to the line to the sun.

The first produces a very small variation, if indeed it can be detected. The second and third cause quite large variations, but at any opposition both distances

are about the same from year to year. The fourth and fifth causes are the main reason for the difference in brightness in the planet at the present time. In 1921 both these quantities were small, so that not only were the rings faintly illuminated, but they were seen at an unfavorable angle. In 1917 the rings were tilted over 20° to the lines drawn from Saturn to the sun and earth.

The nebulae slides, presented to the Society by Mr. Dundas Todd, were then projected on the screen and greatly admired by the audience. The President introduced the lecturer of the evening, Mr. W. E. Harper, who spoke on "The Northern Lights," the popular name attached to the Aurora Borealis.

The lecture was illustrated by thirty coloured slides of auroral displays which had occurred, principally in the Artic regions. The slides, which were very beautiful and added much to the lecture, had been kindly loaned for the occasion by Professor Chant of the University of Toronto. Mr. Harper suggested the possibility of listening to him or other distant lecturers in the near future through the rapid progress being made in the use of the wireless telephone.

The lecturer discussed first where auroras are seen, pointing out their tendency to appear in polar regions and how the frequency curves dip down into the North American continent much more than they do in the case of Europe and Asia. He playfully suggested that our publicity agents had failed to call attention to the very favored position of Canada in regard to these beautiful displays of Nature.

After briefly, touching on their main forms as arcs, bands, rays, curtains and coronas he discussed their variation with the season and with the year. It was found from observation that years of many sun spots were also years of many auroras as also of magnetic disturbances with their accompanying earth currents.

The heights of auroras was determined in 1913 by Stormer and Birkeland using a base line of 17 miles. The great majority of the auroras were found to be at a height of 63 miles, at which height the atmospheric pressure would be comparable to that in a vacuum tube and the marked similarity between auroras and electric discharges through vacuum tubes was commented upon.

An interesting and animated discussion took place on the question of the audibility of auroras, at least a dozen of the audience participating, each giving his individual experience. The majority of the speakers favored an affirmative on the question of audibility.

A hearty vote of thanks was given to Mr. Harper for his most interesting and entertaining address.

A. Symonds,
Secretary.

AT WINNIPEG

Feb. 9.—The meeting was held in the University Arts Building.

The first part of the evening was taken up by a short talk about the Planet Saturn by Prof. Kingston, with special reference to the particularly interesting position of the rings as viewed from the earth at this time. The cause of the different phases of the rings was clearly indicated by the use of a model.

This was followed by a Lecture on the "Einstein Theory—or out-ripping Rip Van Winkle" by Prof. Allen, who gave what was afterwards described as a "most brilliant lecture," the details and ramifications of which are quite beyond the powers of the writer of these minutes to describe, but were nevertheless much appreciated by those present.

Feb. 23.—The meeting was held in the University Arts Building.

The evening was to have been devoted to observational work with the Society's 5-in. refracting telescope, but unfortunately the evening sky was overcast and no observations were possible. In place of these Mr. Bastin described the objects which would have been under observation, viz., Jupiter and Saturn and neighboring objects of interest.

Those present were very much interested and agreed that the lecture helped very considerably to allay the disappointment at not being able to use the telescope.

March 9.—The meeting was held in the University Arts Bldg., the President in the chair.

New members elected: Colin C. Gardhouse, Rathwell, Man.; Archibald Meggett, 16 Manitou Apts., Winnipeg.

Prof. Warren opened the evening with an interesting talk on the constellation of "Orion" and the other prominent objects in that region of the sky. Illustrated with a splendid slide of that part of the heavens. Prof. Warren pointed out the configuration of Orion, the position of Betelgeuse, Bellatrix, Rigel and Saiph the Belt and Sword; specially remarking on the misty star, "the great Nebula.' The positions of Sirius, Procyon, Aldebaran were also indicated. Special prominence was given to Betelgeuse, famous as the first star to be actually measured by the application of the interference of light.

Prof. Carl Miller followed with a paper on "Light as a Wave Motion" which was most interesting and instructive. Many demonstrations were offered by means of different types of apparatus, illustrating many interference effects.

March 23.—The meeting was held in the University Arts Building. Dr. Wilson, President, in the Chair.

New Members: R. A. Macdonald and T. A. Robinson, Winnipeg.

Dr. Kingston gave a short, illustrated talk on the Constellations in the Northern Heavens, pointing out the chief stars and other matters of interest.

The lecture of the evening, "Early Conceptions of the Universe," was given by Prof. Allison, using chiefly Virgil, Dante, and Milton as outstanding examples of ancient opinion. Prof. Allison went on to compare these opinions as expressed in prose and poetry, to those which are held to-day. Many excellent slides, mostly copies of Dore's wonderful pictures, were shown, and the lecture was most interesting and much enjoyed by those present.

April 13.—The meeting was held on the above date in the University Arts Building.

The meeting was opened by the President, Dr. Wilson, who, at the conclusion of the short lecture by Prof. MacLean, vacated the Chair, which was then occupied by the Vice-President, Mr. H. B. Allan.

New members: Mr. C. E. Hammond, 457 Furby St.; Mr. A. Anderson, 114 Spence St.: Mr. J. M. Caldwell, 609 Anderson Ave., Winnipeg.

Prof. MacLean gave a short discourse on the Constellation Leo, enumerating the chief Stars: Regulus, Denebola, and the double star in the Sickle, also pointing out the close proximity of the planets, Jupiter and Saturn.

These short talks, which have been instituted during the present season, upon the constellations of the winter sky and other familiar objects visible at this time, have been very much appreciated, especially by those who are now owners of telescopes, and those of the general public who are not very familiar with the configurations of the constellations.

Dr. Wilson then delivered his lecture on "Comets." Commencing with illustrations of noted comets, quoting dates of last appearance and their periodicity, he proceeded to deal with the peculiarities of their structure, in particular the formation of the tail, *i.e.* the apparent thickening of the edges as compared with the centre, probably caused by the lighter gases being pressed back from the edges of the nucleus, whereas the gases at the extreme head were pressed against the nucleus itself, forming a sort of tube-shaped stream of gas, always attached as it were, to the side away from the sun. The rapid changes which frequently take place were shown on the screen. Dr. Wilson also dealt with the composition, temperature and speed of the comets, pointing out that many of them were supposed to have been drawn into the Solar System through the influence of the planets. The paths of the comets whether hyperbolical, parabolical, or elliptical were described in detail. The comet "Pons-Winnecke" was referred to and the possible results of its visit and close proximity.

C. D. Miller,
Secretary.

At Montreal

March 29.—The meeting was held in the Engineering Building of McGill University, Mr. H. E. S. Asbury, president, in the chair. Attendance 46.

The following were elected members:

Louis V. King, M.A., D.Sc., F.R.S.C., Physics Bldg.

A. S. Eve, M.A., C.B.E., D.Sc., F.R.S., Physics Bldg.

A. N. Shaw, B.A., D.Sc., Physics Bldg.

A. H. S. Gillson, B.A., Arts Bldg.

D. A. Murray, Ph.D., Engineering Bldg.

J. A. Gray, D.Sc., O.B.E., Physics Bldg.

All Professors of McGill University; nominated by James Weir.

W. H. Smith, Supervisor Protestant Schools, Montreal, 215-B Mount Royal Ave., Montreal.

D. C. Bates, B.A., Principal Riverside School, Favard St., Point St. Charles, Montreal.

Nominated by F. R. Robert.

R. G. Oliver, 328 Wood Ave., Westmount.

A. S. MacIntosh, 1024 Dorchester St. W., (Apt. 5), Montreal.

Andrew O'Connor, 157 Laporte Ave., Montreal.

Nominated by H. E. Markham.

The President then called upon the speaker of the evening, D. R. Proctor Coates, one of our members, to address us on "The Life and Works of Richard A. Proctor." Mr. Coates, who is a grand nephew of the late Richard A. Proctor, was naturally well qualified to give us an int'mate view of the life of this eminent scientist, and did so in a most entertaining manner. The address was profusely illustrated with lime-light views. The late Mr. Proctor's investigations into the science of astronomy and his numerous works on the subject, were but briefly touched upon by the lecturer, no doubt through family modesty. Mention was made, however, of Mr. Proctor's well-known charts, including the mapping of some 324,000 stars in the Northern Hemisphere alone, and some of his works, including "Other Worlds Than Ours." He also contributed a large number of popular essays. His lectures were still more popular. It was interesting to learn he gave several lectures in this city in 1879, and the Montreal "Star's" report on them was shown on the screen.

A hearty vote of thanks was accorded the lecturer.

The meeting concluded with the singing of the National Anthem.

April 26.—The meeting was held in the Physics Building of McGill University, the president being in the chair. There was an attendance of 76.

The following were elected members:

Orrin Rexford, Montreal High School, 308 Prince Arthur St., Montreal.

F. McNealy, Montreal High School, 1645 Park Ave., Montreal.

Norman Knight, Engineering Dept., Bell Telephone Co., Montreal.

Arthur F. Gault, 75 Mount Royal Ave. W., Montreal.

W. H. Winterrowd, Chief Mechanical Engineer, Canadian Pacific Ry., Montreal.

All nominated by H. E. S. Asbury.

Mr. George Sample exhibited a model of the Precession of the Equinoxes, and gave a short talk upon this subject. The model, made by Mr. Sample, was greatly admired, and with its aid, he had no difficulty in making the matter clear to his audience. In the course of his remarks, Mr. Sample stated the Precession occupied a period of 25,868 years, and pointed out that the obliquity of the ecliptic was maintained throughout. The Southern Cross will be visible to the inhabitants of Montreal 13,000 years hence.

Professor A. S. Eve gave an address on "The Rotation of the Earth." The observations of Ptolemy and others, with their theories, were related. After a lapse of some centuries of darkness, came the discoveries of Bacon, Copernicus, Galileo and Newton, which were described by the lecturer. The address broadened into the subject of Rotation in general, and touched upon Einstein's theory of relativity. Prof. Eve was inclined to discredit the newspaper reports of Brush's experiments, which, if correct, would upset this and other theories. The lecture was illustrated by lime-light views, and by numerous experiments, including some novel and interesting experiments with the gyroscope.

The meeting concluded with the singing of the National Anthem.

H. E. MARKHAM, *Recorder*

(*Other minutes held over until next issue*).

NOTES FROM THE METEOROLOGICAL SERVICE

MARCH, 1921

TEMPERATURE

The temperature was from average to 1° and 2° below over the greater portion of British Columbia, also in the Northern parts of Alberta and Saskatchewan as well as locally in Manitoba, otherwise over the Dominion it was above the average and nearly everywhere to a marked extent, the positive departure varying from 3° to 9° in Ontario, from 2° to 8° in Quebec, and from 2° to 7° in the Maritime Provinces.

TEMPERATURES FOR MONTH OF MARCH, 1921

STATIONS	March Highest	March Lowest
Yukon		
Dawson	32	−32
British Columbia		
Atlin	42	−26
Agassiz	62	25
Barkerville	49	−14
Kamloops	63	10
New Westminster	57	30
Prince Rupert	50	16
Vancouver	58	29
Victoria	56	30
West Provinces		
Battleford	47	−24
Calgary	57	−31
Edmonton	55	−21
Medicine Hat	60	−18
Minnedosa	44	−21
Moosejaw	59	−11
Oakbank	42	−20
Prince Albert	45	−34
Qu'Appelle	50	−16
Regina	55	−14
Saskatoon	45	−25
Souris	..	..
Swift Current	58	−18
Winnipeg	44	−14
Ontario		
Agincourt	68	5
Oak Ridges	64	2
Bancroft	60	− 3
Barrie	64	2
Beatrice	60	0
Bloomfield	62	5
Chapleau	42	−27
Chatham	59	13
Clinton	70	10
Collingwood	55	4
Cottam	40	10
Georgetown	53	4
Gravenhurst	62	0
Grimsby	72	9
Guelph	65	7
Haliburton	62	− 6

STATIONS	March Highest	March Lowest
Ontario—cont.		
Huntsville	62	− 5
Kenora	47	−23
Kingston	66	8
Kitchener	60	4
London	71	12
Lucknow	69	0
North Gower	45	− 5
Oshawa	37	9
Ottawa	66	−18
Paris	69	10
Parry Sound	62	− 3
Peterborough	53	− 1
Port Arthur	45	− 8
Port Burwell	45	7
Port Dover	..	..
Port Stanley	59	5
Queensborough	69	6
Ronville	47	−14
Southampton	69	9
Stonecliffe	70	−18
Stoney Creek	70	11
Toronto	70	7
Uxbridge	50	0
Wallaceburg	35	10
Welland	56	9
White River	55	−42
Quebec		
Brome	67	− 3
Father Point	56	−10
Montreal	68	3
Quebec	53	− 1
Sherbrooke	69	− 1
Maritime Provinces		
Charlottetown	56	12
Chatham	64	4
Fredericton	64	5
Halifax	56	12
Moncton	64	5
St. John	56	8
Sussex	64	5
Sydney	54	8
Yarmouth	58	2

Precipitation

The precipitation was below the average over a large portion of British Columbia, but above locally, more especially in the Cariboo district. In Alberta and Saskatchewan it was above in nearly all localities, while in Manitoba it was for the most part below. In Ontario, except locally, it was above the average as it was also in the Maritime Provinces; whereas, in Quebec it was well above over the Western and central portions, diminishing to about the average over the eastern boundary of the Province. The precipitation from Ontario to the Maritime Provinces was chiefly as rain.

SEISMOLOGICAL NOTES

During the month of March Toronto recorded 19 disturbances and Victoria 18. This is the largest number we ever recorded in any March, and is 12 greater than the normal number. The majority of them were of small amplitude. The Nicaragua quake of the 28th was the largest of the month. It gave a trace amplitude of 5 MM at Toronto and 5.5 MM at Victoria. The preliminary waves were recorded at Toronto at 7h 55m 42s, and the Maximum portion at 8h 8m and the waves continued for 2h 24m. Victoria recorded the Maximum waves at 8h 21m 37s. No great damage was recorded in Nicaragua. J. Y.

Magnetic Disturbances—FEBRUARY, 1921

No important perturbations of the magnetic field of the earth were recorded at Agincourt or Meanook during the month of February. On 14 days no report of the aurora was received and on other days only from a few scattered places in the Western Provinces was a 3rd or 4th class aurora reported. Sunspots were also scarce and what few were visible were very small. A small sunspot group was central on the sun's disk on the 18th and apparently increasing in size and numbers up to its disappearance around the limb. W.E.W.J.

ASTRONOMICAL NOTES

A POSSIBLE CAUSE OF NOVAE

On the Passage of a Star Through a Nebula (by Ernest W. Brown, *Ap. J.*, *53*, p. 169).

Professor Brown discusses theoretically the effects produced by the passage of a star through a nebula consisting of a swarm of particles. Neglecting the effects of mutual collisions between the particles and the gravitational attraction of the swarm on its constituents, Professor Brown shows that all the particles at a distance b from the star will cross the path at the same point at a distance $b^2/2a$ behind the star where a is the ratio of the mass of the star to the square of its speed. As a result of the collisions occurring on account of this convergence, these might produce a gaseous appendage of a conical form. This theory is then applied to explain the appearance of Hubble's variable nebula which consists of a nucleus of a variable star and a fan-shaped appendage which also varies in form and brightness. Making certain assumptions as to the probable mass it is shown that the parallax of the object should be between one-tenth and one-thousandth of a second and may be possible of determination trigonometrically. The variation in brightenss may be due to local variations in the density of the swarm.

As the spectrum of this object resembles that of a nova in its earlier stages, this is interesting in view of the theory that novae are produced by the passage of a star through a nebula. The author states that other nebulae show that the fan has sometimes nearly parallel sides indicating greater relative velocities of swarm and star. The appearance of these nebulae will evidently vary with the apparent direction of motion; from the fan, through an oval-shaped nebulosity with the star away from the centre, to a circular nebulosity surrounding the star, with probable analogy to planetary nebulae. J. S. P.

THE MOTION OF SPIRAL NEBULAE NOT DUE TO RADIATION PRESSURE

Radiation Pressure and Celestial Motions (by Henry Norris Russell, *Ap. J.*, *53*, p. 1).

In view of Shapley's recent hypothesis that the general recessional motion of the spiral nebulae may be due to repulsion by the Galaxy, Professor Russell computes the maximum possible repulsive effect. He shows that the radiation pressure of the Galaxy on the two nebulae, Andromeda and N.G.C. 4594, for which sufficient data are known, is exceedingly small. Acting on the Andromeda nebula for 100 million years would only produce a velocity of 3.5 km per sec. as compared with its measured velocity -316 km per sec. Assuming a distance of 200,000 parsecs, radiation pressure would only reduce its velocity 23 km per sec. in the time required to reach the Galaxy at its present velocity. For N.G.C. 4594

the effects are very much smaller. He shows that electrostatic charges sufficient to overcome gravitational attraction would even in planetary, let alone stellar, bodies disrupt their surfaces so the charges could not be held. He gives additional proof by showing that a repulsive force of any nature sufficiently great to produce the observed velocities must inevitably so deform the spirals as to be apparent in photographs of these objects. It is proved that in general the gravitational attraction of the Galaxy would be very much greater than any possible radiation pressure or other known repulsive action, but that even this is insufficient to account for the magnitude of the velocities of the spirals—to say nothing of their sign. He concludes by saying it is more important to increase the data available than to discuss the hypothetical possibilities of the action of unknown forces.

J. S. P.

UNITS IN ASTRONOMY

(Letter from Dr. John Satterly regarding an abstract in last issue, p. 169)

I was glad to see that the American Section of the International Astronomical Union recommends as a unit of pressure, "One bar" $=10^6$ dynes per sq. cm. The so-called normal, or standard, atmospheric pressure of the physicist and chemist is that equal to the pressure exerted by a column of mercury at 0°C and 76 cm. high at sea level in latitude 45°. This is approximately 1.01×10^6 dynes per sq. cm. This pressure is higher than that which is usual over continental highlands like a great part of the United States, and many experimenters in those regions have recommended as a standard a height of 75 cm. of mercury. It is, however, better to stick to the 76 cm. as a large mass of data now refers to it.

The only objection one can have to the bar as the unit of pressure is that one can hardly visualize it, except by comparison with a liquid column. One of the chief American research institutes has, however, complicated matters by defining the bar as one dyne per sq. cm. So that the millibar of the meteorologists may be confused with the kilobar of the research physicists of the General Electric Company.

This habit of changing units is one of the chief hindrances to the acceptance of the Metric System by the people at large. No sooner is a unit defined than some section of scientific workers wants a unit ten times as large or as they may stupidly remark ten times as small. For example, the American Section of the International Astronomical Union wants a unit equal to 10 parsecs for measuring distances. Why? What a mistake was made when the ampere was defined as one-tenth of the C.G.S. unit of current? What trouble and worry it has given to thousands of students in electricity!

My objection to the joule as a unit of heat is that it cannot be readily visualized in terms of the unit mass, and the one degree centigrade. One caloric $=4.2$ joules approximately, and if there is trouble in defining the particular 1°C at which the calorie shall be defined there is just as much trouble in finding the exact value of the acceleration of gravity which enters into the composition of the joule. I think it is far preferable in general to measure heat by a heat unit than by a work unit.

(A letter was also received from Professor McAdie, of the Blue Hill Observatory, regarding the value of 1 bar, and some other matters.—ED.)

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

THE WEATHER IN THE NORTH-WEST

There has recently been issued by the Meteorological Office an extensive publication on *The Temperature and Precipitation of Alberta, Saskatchewan and Manitoba*, by Mr. A. J. Connor, M.A., Climatologist of the Meteorological Service. In 1915 a similar volume, relating to British Columbia, was published.

It contains a mass of tabulated results, reaching back in some cases to 1874, and accompanying the volume are maps showing the temperature during each month and also the precipitation at the different seasons.

It is interesting just now, when the southern Albertans have a professional rainmaker at work, trying to procure the much desired precipitation, to see just what the average rainfall has been. It is recorded that at Medicine Hat, during the months May to June the average of 34 years (1883-1917) has been 7.66 inches. At Lethbridge the average for 26 years (1886-1912) was 9.84 inches. I understand that $2,000 an inch is to be paid for half the amount of rain obtained up to 8 inches, and from the above record it would seem that our U.S. operator has shown his proverbial shrewdness by not taking chances which are too high against him. The volume runs to 170 pages, quarto size.

WINNECKE'S COMET

This comet has aroused great general interest as it was predicted that the earth might come into collision with it towards the end of June. This, however, will not take place, though the comet will comer closer to us than any other heavenly body except the moon.

The comet was originally discovered by Pons, at Marseilles, on June 12, 1819. Encke computed its orbit and predicted its return in 5.62 years; but it was not seen again until March 8, 1858, when Winnecke, at the Bonn Observatory, discovered it. Since then it has returned eleven times and it has been observed on eight of these occasions. It was rediscovered by Barnard, by photography, on April 10, and its orbit as computed by Professor Crawford and

Miss Levy, from observations on April 12, 19 and 29, gives the following elements:

Time of perihelion passage.....1921, June 12.95 G.M.T.

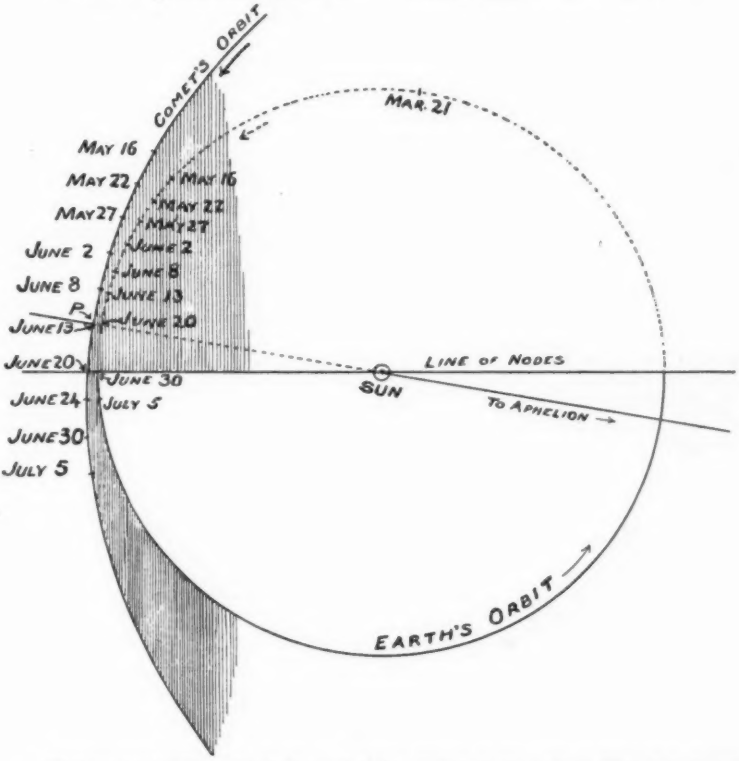
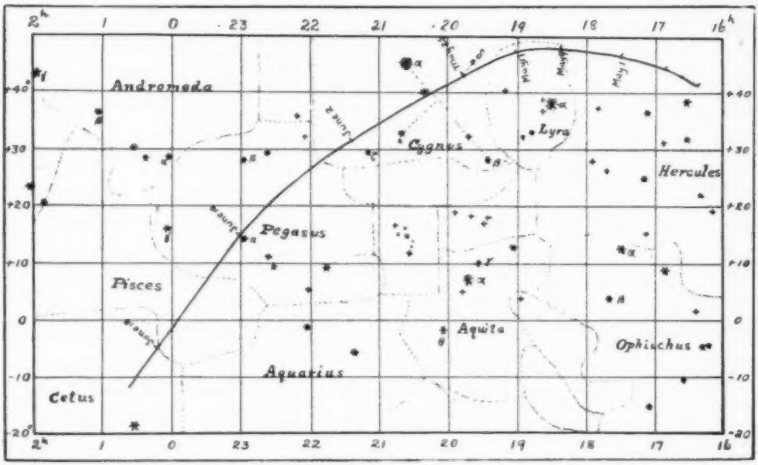


Diagram showing the orbit of the earth and a portion of the orbit of Winnecke's Comet together with the positions of these bodies at various dates. The angle between the planes of the orbits is about 19°. *P* is the perihelion of the comet's orbit.

Perihelion minus node.....170° 34′.
Longitude of node..... 97° 51′.
Inclination..... 18° 50′.
Perihelion distance.....1.040.
Eccentricity.....0.6779.
Periodic time.....5.80 years (assumed).

The comet will arrive at the descending node about June 20, while the earth will not be there until about June 30.

The orbit in space, and also the path among the stars, are given in the accompanying diagrams.



Path of Winnecke's Comet among the Stars (By R. K. Young, Victoria, B.C.).

OTTAWA OBSERVERS FOR THE ARCTIC

J. P. Henderson, A. H. Swinburn and A. H. Miller, of the Staff of the Dominion Observatory, left in the last week in April for the Mackenzie region to make latitude and longitude determinations, as well as gravity observations.

It is expected to put in seven stations, the most northerly one being at Fort Macpherson, near the mouth of the Mackenzie and within the Arctic circle.

The longitude determinations will be by wireless, receiving time signals not only from Annapolis but also from the powerful station at Bordeaux; the former sends out wave-lengths of 17,000 meters and the latter of 22,000 meters. Some interesting results are expected from the gravity observations, especially from the high latitude in which some of the observations will be made. The immediate reason for the observations, particularly the astronomical ones is for co-ordinating the recently discovered oil fields near Fort Norman, on the Mackenzie.

The observers are not expected back before October.

C. A. C.

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